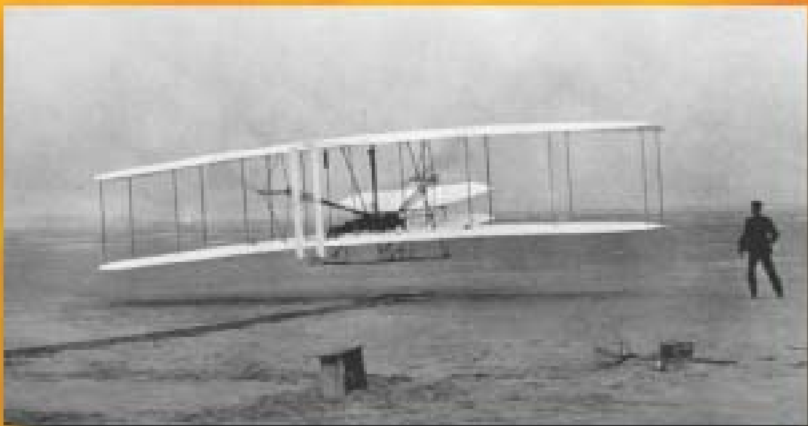

History Of Powered Flight

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HISTORY OF POWERED FLIGHT

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INTRODUCTION

It is easy to invent a flying machine; more difficult to build one; to make it fly is everything. These words of Otto Lilienthal (1848–1898) bear testimony that modern aviation is a result of efforts of thousands of people over a very long period of time and is in a constant state of evolution. History was made on December 17, 1903 on the wind-swept sand dunes of Kitty Hawk (North Carolina), when the Wright brothers made the first powered heavier-than-air airplane flight with a degree of control. This historic achievement ushered an era of rapid progress during which brave men and women conquered the skies and began venturing into space.

This article commemorating the 100th anniversary of the Wright brothers' first flight, attempts to highlight the untiring efforts of people in aviation history. The significance of these early efforts to fly from George Caley's glider to the latest Airbus A-380 and the development of aviation in India from JRD Tata's pioneering efforts to the indigenous development programmes of a 2 seater light plane (Hansa), a 14 seater light transport multi-role aircraft (Saras), the Light Combat Aircraft (Tejas) and the Advanced Light Helicopter (Dhruv) are touched upon. In brief, it traces the formative and the recent years of aviation. It spans the period from 1890 through Wright brother's impact, first passenger airplanes, engine development when the pilots competed for air races to the present scenario, when any point on earth can be reached in only a few hours by air.

EARLY ERA (1890-1903)

Pre-Flight History: The best-known Greek legend on the subject of flight is that of Daedalus, who was imprisoned along with his son, Icarus by King Minos, but they escaped by making themselves wings of wax and feathers. Similarly a tale was written in 1638 titled *The Man in the Moon*, in which the hero supposedly trained a flock of geese to fly him to the moon. Birds and later on fish inspired man to explore the principles of flight and movements through the air. One early attempt to construct a flying machine was by Leonardo da Vinci (1452-1519) with a flapping wing aircraft, powered by the human body called ornithopter around 1500. The first aerial journey was made in a hot air balloon in 1783 over Paris by Montgolfier brothers (16).

Early Flight History

Sir George Cayley known as the "Father of Aerial Navigation" designed the first airplane with wings, fuselage, tail unit and a means of propulsion in 1799. He was the first to identify the four forces of flight viz; thrust, lift, drag, and weight and also to describe the relationship between each other. The invention of fixed-wing aircraft concept happened in 1804 when he flew the first successful model airplane which had a kite-shaped wing mounted on a pole with a universally jointed tail unit (**Figure 1**). In 1849, a small boy became the first person in history to make a short flight in a Cayley glider (11, 16). Clement Ader's (France) incredible steam-powered bat-wing airplane, the `*Eole*' (**Figure 2**) is the first heavier-than-air machine, which climbed about 8 inches in the air and flew, for 160 ft. in 1890. The French claim that Ader beat the Wright brothers in the race to fly by 13 years (11).

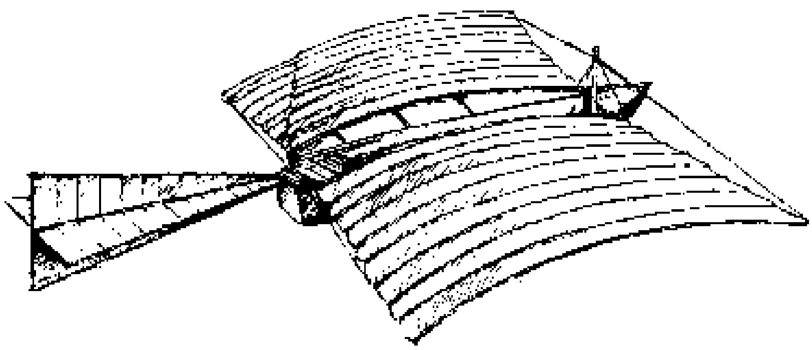

Figure 1. George Caley's Glider

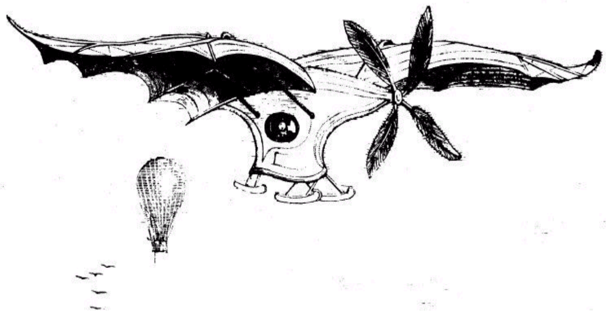

Figure 2. Clement Ader's `Eole"

Otto Lilienthal (Germany) known as the `Aviation's practical father' launched himself from a small hill at Berlin in 1894, using his carefully researched understanding of flight to hang-glide, controlling the flight with his body. If Lilientahal had attached one of the new automobile petrol engines to large version of his gliders, he would probably have been the first to achieve sustained, controlled, powered flight. Lilienthal was killed in a gliding accident in 1896, but his writings and photographs helped others to persuade that manned flight was possible. A replica of Otto Lilienthal's glider at Hannover Museum, Germany is shown in **Figure 3**.

Figure 3.
Lilienthal's glider

An Anglo-American inventor Sir Hiram Stevens Maxim made a test rig biplane powered by two small steam engines in 1894. The engines and boilers were coaxed to deliver greater and greater pressure until, when exceeding 67 kmph; the whole structure took to the air. It lifted with such a force that it broke the restraining track and flew about 200 ft. and crashed. Its main contribution to aviation was a startling curiosity.

The Zeppelin (a German firm) built a series of lighter than air vehicles `Airships' (**Figure 4**) between 1900 and 1936 which made their own contribution to aviation history including aerial cruises and reconnaissance flights. The Graf Zeppelin, the most successful airship had its first flight in 1928 and later it pioneered passenger travel over the Atlantic long before airplanes. These airships were withdrawn from service, following a disaster in 1938. Another milestone was when Karl Jatho (Germany) made few short hops into the air, the best of which was when he flew his powered glider for a distance of 18 metres for 45 seconds in 18 August 1903. A replica of Karl Jatho's biplane is shown in **Figure 5** (12)**.**

Figure 4. Zeppelen Airship

Figure 5. Karl Jatho's biplane

BEGINNING YEARS (1903 - 1915)

Wright Brothers

Wilbur and Orville Wright brothers of America founded the Wright Cycle Co., in Dayton, Ohio, in 1892. Wright's early experiments of flying began in 1900 by manipulating the wing surface of their glider to react to the wind and by 1903 it gained a rudder. Wing warping and stabilizing was done by wires attached to the feet, but was not always successful. On Dec. 17, 1903, with Orville at the controls, the 'Flyer' lifted off shakily from Kitty Hawk (North Carolina) and flew 120 ft. (**Figure 6**). It was driven by a gasoline powered 12 hp internal combustion engine, weighing 152 lb (12.6 lb per hp) and achieved a speed of 10 kmph. That

12 seconds flight changed the world, lifting it to new heights and giving mankind access to places it had never before dreamed of reaching. Wilbur demonstrated a 1907 model flyer at Le Mans in August 1908, and showed it to King Edward VII at Pan, France in 1909. While giving a government demonstration at Fort Myer, Virginia in September 1908, Orville crashed, killing his passenger Lt Thomas (5).

How they achieved the feet and gave us a flying tool?
Wright brothers built their own wind tunnel around 1900 to test airfoils and measured empirically how to lift a flying machine. They discovered that a long, narrow wing shape was the ideal architecture of flight. They built a forward elevator to control the pitch of their craft as it nosed up and down. They fashioned a pair of twin rudders in back to control its tendency to yaw. They devised a pulley system that warped the shape of the wings in mid-flight to turn the plane and to stop it from rolling.

Other Developments following Wright Bothers

Perhaps the second greatest advance, after the Wrights' first flight was in January 1908, when Henry Farman successfully flew Voisin biplane over a kilometer in France. But, the practical potential of the airplane was realized when Louis Blériot of France flew his monoplane IX across the English Channel on 25 July 1909 (**Figure 7**) (11). It is believed that the fashion for monoplanes developed after Blériot's channel crossing. In 1911 the Deperdussin Company in France built a trim, single seat-racing plane that heralded the sleek aerodynamic designs of later years. It not only won the Gordon Blennett Trophy in 1912, but became the first plane to exceed 160 kmph, in the process setting a new world speed record of 172 kmph.

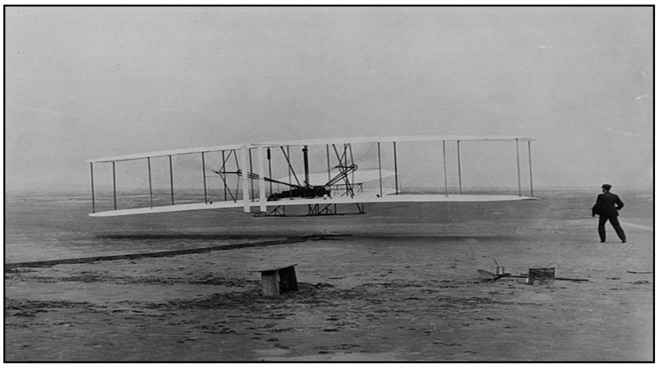

Figure 6. Wright brothers' 1903 first flight

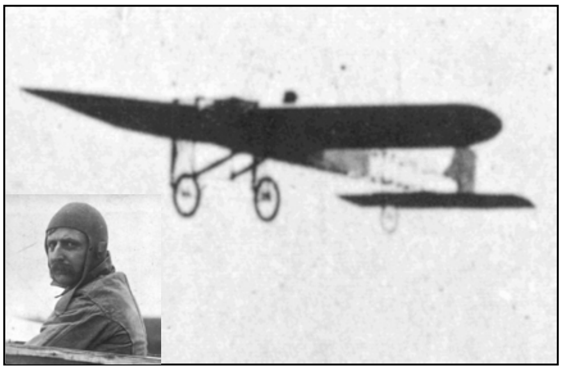

Figure 7. Blériot and his monoplane

The early airplane designers and builders reasoned that biplane would provide more lift than a monoplane of the same span, but they soon found drag was caused by inter-plane interference, the resistance offered by the struts to the flow of air and other factors, which they had not expected. The early biplane designers also argued that even if they had a deep airfoil section and the proper materials for building cantilever wings, the biplane was structurally more efficient. Due to these reasons, the conversion from biplanes to monoplanes was a slow process. Until 1908 aviation could counter engine weight only by making aircraft lighter and producing greater lift from a larger wing area. Due to this, the concept of biplanes and eventually triplanes was popular. The better success of triplanes began when A.V.Roe's Avroplane modelled on the Goupy triplane first flew in 1909. However, the advent of the rotary engine with improved power to weight ratio, and the monocoque construction, favoured the development of the monoplane, which is by far the choice today.

Seaplanes: Frenchman Henri Fabre created the first flight of a seaplane called Hydravion. Using a 50 hp Gnome rotary engine, Fabre flew 1650 ft. over water in 1910 at Martigues(14). Although the first seaplane was flown by Henri Fabre, the great pioneer of marine flying was Glen Curtiss of the United States. These were precursor to the later golden age of flying boats (1930-1940). These boats won thousands of air travellers because of the pleasant air journies.

Flying-headaches and ground accidents: A pilot's reputation was fragile. Ground accidents were common: brakes were primitive, grass surfaces were bumpy and there was no standard training. Returning from a record-breaking American tour, the pioneer Hubert Latham crashed his Antoinette onto a roof (**Figure 8**) at Brooklands in 1911. Earlier to this incident, a little taxiing monoplane crashed into the river Way at Brooklands. In spite of the risks involved in flying, the fashion to fly continued and moreover there were compelling attractions for air races. **Figure 9** shows Winston Churchill and his wife Clemente visiting Hendon air show in 1914.

Figure 8. Aircrash (1911)

Figure 9. Compelling attractions

Monocoque construction

A monocoque (means single shell) fuselage relies on the strength of the skin or shell to carry the loads. The first wooden monocoque structure was designed by the Swiss Ruchonnet and applied to a Deperdussin monoplane racer by Louis Béchereau in 1912. In 1918, Jack Northrop devised a new way to construct a monocoque fuselage for the Lockheed S-1 racer. In 1920s the airframes were invariably of wooden frame construction with fabric covering. The breakthrough was made in 1930s with the use of monocoque construction using aluminum alloys-skin. This led to a dramatic increase in the strength of the structures besides permitting more streamlined construction (**Figure 10**) (8,17). A classic example of such a design was the Douglas DC-3 aircraft, which revolutionised air transport in 1930s and 1940s.

Commercial air transport – beginning

JUNKERS F-13 (**Figure 11**) was the first modern commercial transport aircraft with all metal (duralumin) construction. This German aircraft first flew in 13 Sept 1919 at an altitude of 22,000ft. The seating capacity of this aircraft was 4. With the advances in aircraft design brought about by World War-I, the Trimotor airplane became the standard for commercial airline travel by the early 1920s with a capacity of 12 passengers and speed of 180 kmph.

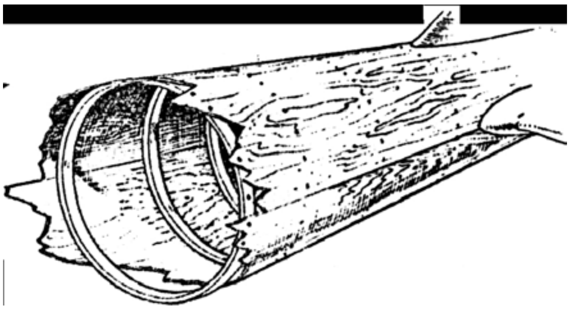

Figure 10. Monocoque construction of fuselage

Fig 11. First commercial transport aircraft, Junkers F-13

ENGINE DEVELOPMENT

Early Airplane Engines

The engine designed and built by Charlie Taylor and the Wright brothers for their Flyer, although much lower powered, have a great place in history because they propelled the first successful powered flight in 1903. The earliest aero engines were either radial in design or inline. There are two types of radial engines. The most commonly used radial engine was the 50 hp Antoinette (**Figure 12a**) was designed and built by Léon Levavasseur (France) in 1910. Its weight-to-power ratio (2.2 lb per hp) was not surpassed for next 25 years. These were succeeded by rotary engines in which radially disposed cylinders rotate around an axis. This gave better cooling of the engines and hence gave more power and also had improved reliability. The Australian Lawrence Hargrave built a three-cylinder rotary engine in 1889. The best-known rotary engines were the Gnome (**Figure 12b**) (11,18) and Le Rhone, which were used on a majority of aircraft during World War I. The Wankel rotary engine was invented by Felix Wankel in 1936 and is based on a lobed rotor running inside a trochoidal cavity (**Figure 13a**). Such engines are now finding applications in light aviation. A powered hang glider (PHG) has been flown with a Wankel engine in National Aerospace Laboratories (NAL), Bangalore in 1997 (**Figure 13b**).

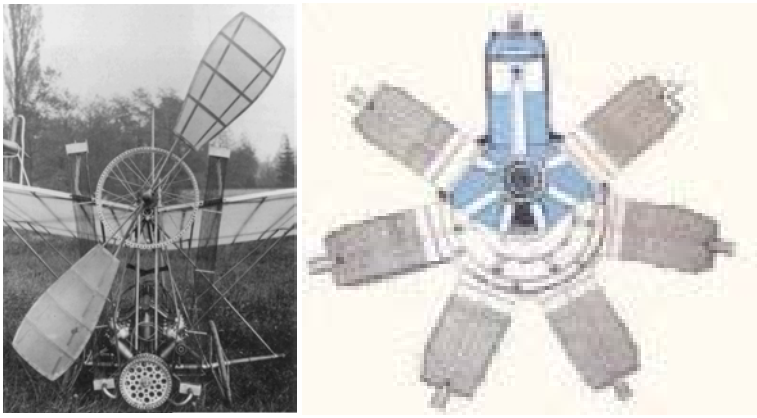

Figure 12a.
Antoinette radial engine

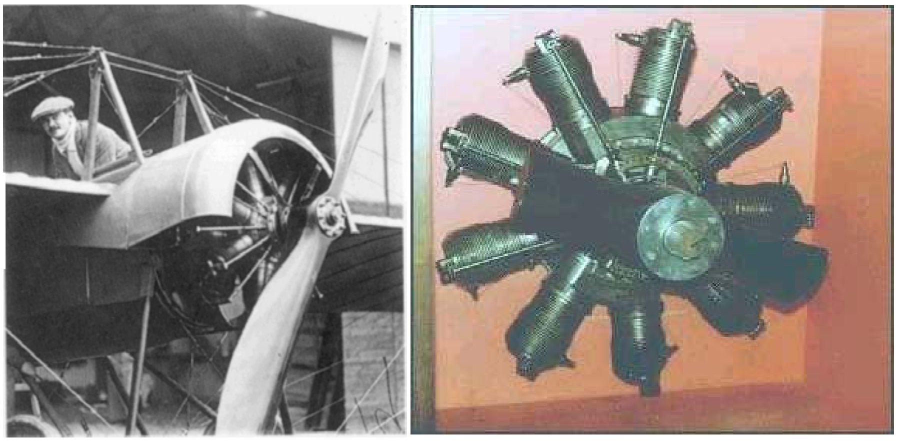

Figure 12b.
Gnome rotary engine

Figure 13a. Wankel rotary Engine

Figure 13b. Powered hang glider flown with Wankel engine at NAL

Break through in Engine Development

The limitations of the propeller driven by piston engines were realized due to a drop of efficiency of the propeller at high speeds due to the onset of compressibility effects. Air races provided the motivation to go for more powerful and efficient propulsive systems. Impressive speed records were achieved in Hendon’s first international air race in 1913. In the Schneider trophy, the speeds achieved were 509 kmph (1928) and 570 kmph (1929).

Evolution of Jet Propulsion

The first effort to employ jet propulsion can be traced back to Hero's reaction turbine (**Figure 14**) called the "aeolipile" which was developed in 100 B.C in Egypt. Much later, in 1687 a Dutchman employed the reaction of steam jet to drive a carriage as shown in **Figure 15** (20).

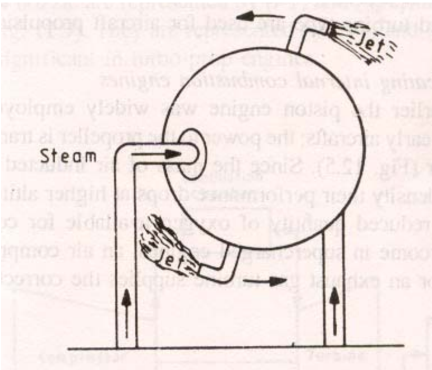

Fig 14. Hero's reaction turbine

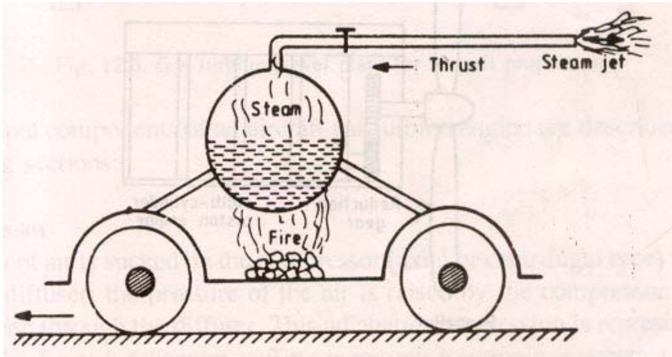

Fig 15. Stream jet driving a carriage

Sir Frank Whittle of England was totally fascinated by the challenges of high-speed flight. He graduated from the Royal Air Force College in 1928 and his thesis discussed gas turbines and jet propulsion. In a 1930 patent application, he outlined the concept of the modern turbojet engine. Delayed by funding difficulties, he got a test model running in 1937. The first successful flight of the engine designed by him was in 1941.

As a young doctoral student in Physics at Göttingen University, Hans J.P. von Ohain of Germany, totally unaware of Whittle's work, arrived at a similar solution: that to achieve speeds higher than 480 kmph, a form of propulsion other than the piston engine and propeller was required. He quickly got commercial backing for his research. By 1937, he successfully tested an engine and first successful flight of the engine was in 1939 (10).

Frank Whittle (1907-1996)

Hans Ohain (1911-1998)

Turboprop Development

In early 1940s some advanced thinkers were already prepared to anticipate the use of turbine engines. In a turboprop engine a propeller is driven by a gas turbine engine. The propeller creates the main thrust from the engine. It offered greater speed and power than the piston engines and better fuel economy compared to the turbojet for speeds up to about 700 kmph. The first successful aircraft, the Gloster Meteor flew with a turboprop engine in Britain in 1945. The Junkers 022 turboprop was made in 1945. Prior to this efforts were also made in Junkers Aircraft Company (Germany) with the help of Herbert Wagner, but the turboprop developed by them in 1942 did not enter any flight programme (4, 10).

Turbofan Engines of late 1950s

In a turbofan engine, one or more rows of compressor blades extend beyond the normal compressor blades and results in pulling more air compared to a turbojet. Most of this excess air is bypassed around the power section and out with the exhaust gases. Advantages are better performance at a lower rate of fuel consumption and less noise. Boeing 707 first flew in 1952 with a turbofan engine. The first long-range services started with turbofan engine in 1968 with 250 passengers.

As shown in **Figure 16**, the turboprop is preferable for lower range of speeds 280 mph (450 kmph). The performance of turbofans is maximum at around 750 mph (1200 kmph) and that of turbojets continuous to improve with speed.

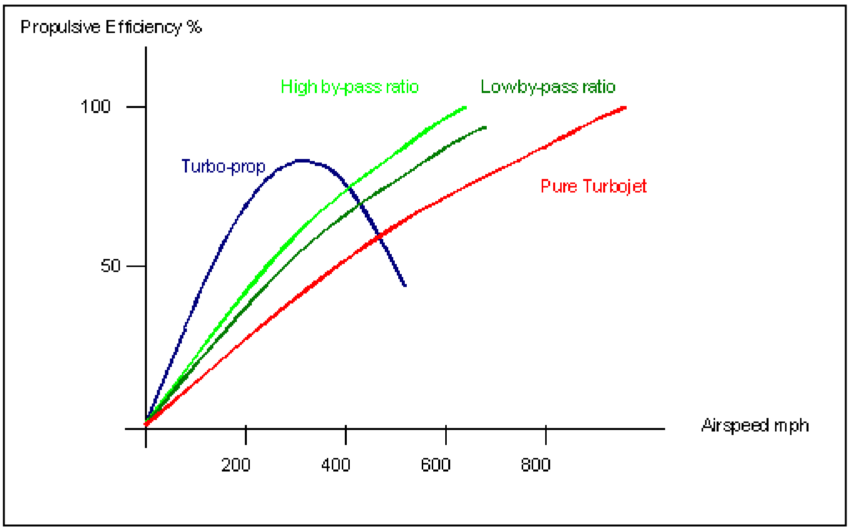

Figure 16. Propulsive efficiency of engines

MODERN PERIOD

The salient features of some of the developments during this period are briefly outlined.

Lockheed Constellation (Connie) was designed in 1939 for long-range commercial transport and put in service from 1946. The original Constellation (L-049) flew at a speed of 480 kmph with a seating capacity of 44. L-1649 remained in service till the arrival of jet airplanes.

The world's first jet-powered commercial airliner, the De Havilland Comet (**Figure 17**), began regular service in 1952 for British Overseas Airways Corporation. It cruised at nearly 800 kmph with a passenger capacity of 36. Unfortunately, the early Comets had an undetected and fatal flaw. After two Comets disintegrated in midair within four months in 1954, they were withdrawn from service. De Havilland restarted its services in 1958 with Comet 4 having a stronger airframe. This became the first jetliner to provide service across the Atlantic ocean.

Boeing 707, the long range transport aircraft had its beginning in the early 1950s. Boeing started production in 1952 and two years later completed its maiden flight. B-707 made its inaugural nonstop flight from New York to Paris in 1968. The aircraft could carry as many as 200 passengers at 1,000 kmph. It was so safe and reliable that it was selected as the official aircraft of the President of USA before being replaced by a Boeing 747.

Sud Caravelle (**Figure 18**) was the most successful commercial jet aircraft ever produced in Europe for short to medium range. The seating capacity ranges from 80 to 128 between the earliest (1959) and latest (1970) versions. The cruise speed was 830 kmph at 25,000ft. and the range was 4000 km. The Caravelle served in Indian Airline Services till 1962 when its fleet was replaced by the Boeing 737s.

In 1962, the French and British governments decided to take up the development of the Concorde, the world's first supersonic transport aircraft (**Figure 19**) and it made history in aviation. The aircraft had its maiden flight at Toulouse in 1969. It can carry 100 passengers from New York to Paris in less than four-hours (about half of the travel time by a conventional passenger jet). The Concorde's cruising speed is Mach 2.2 (more than twice the speed of sound) or 2300 kmph at 65,000ft. and its range is 5800 km. A unique feature of the Concordes' design is its needle-sharp (drooped) nose section, which can be angled downward during takeoff and landing to have an unobstructed view of the runway. Due to a crash and high maintenance and fuel costs, the aircraft has been partially withdrawn from service and the complete withdrawal is expected by 2003 (6,7,16).

Figure 17. De Havilland Comet

Figure 18. Sud – Caravelle

Figure 19. Concorde

Due to the advancement in technology, the dramatic improvements in performance and unit size are evident; engine powers (few lbs to 100,000 lbs), speeds (from 10 kmph to Mach 2.2: 2300 kmph) and carrying capacity (single/two persons to 555 passengers) over the years. **Figure 20** and **Figure 21** shows these improvements in travel time and carrying capacities respectively (2).

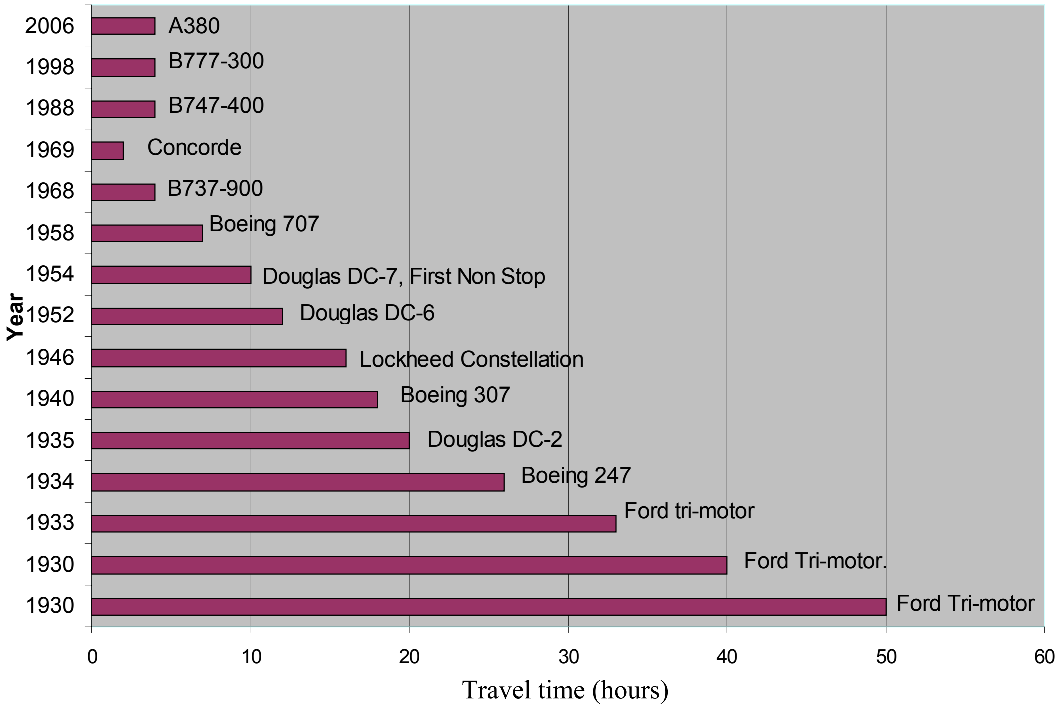

Figure 20. Improvement in travel time (New York to Los Angeles: 3950km)

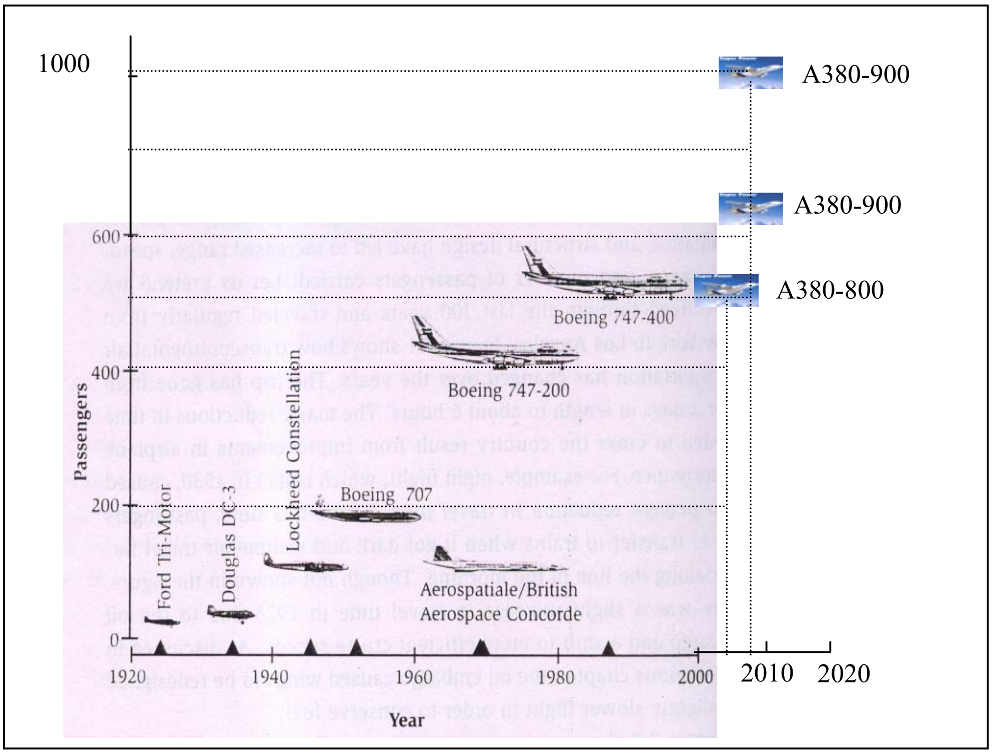

Figure 21. Improvement in passenger capacity

The launching of a new range Boeing 777-300 (**Figure 22**) airplane brings the comfort and economic advantages to non-stop routes that have never before been possible. The first 777-

300ER rolled out in 2002 and completed maiden flight in February, 2003. It is configured up to 550 seats. The typical cruise speed at 35,000ft is 0.84 Mach and the maximum range is 11,000km. The service entry is expected in March 2004 (19).

The development of a new large-capacity aircraft, Airbus A-380, double-decker jumbo jet (**Figure 23**) began in 1999. Depending on the version, it would carry from 555 to 850 (in high density 1000) passengers. The maximum range it could fly varies from 11,400 km to 22,200 km (imagine this distance!). This aircraft is expected to have improved fuel consumption and operating cost. About 40 percent of the structure and components would be manufactured from composite materials. Service entry is expected in 2006 (19).

Figure 22. Boeing 777

Figure 23. Airbus A-380

INDIAN AVIATION

The history of civil aviation in India began in December 1912 with the opening of the first domestic air route between Karachi and Delhi by the Indian State Air services in collaboration with the Imperial Airways, UK, though it was a mere extension of the London-Karachi flight. The first Indian airline, Tata Sons Ltd., started a regular airmail service between Karachi and Madras (Chennai) in 1915 without any patronage from the government. J R D Tata, a visionary who had founded the first Indian airline, piloted the inaugural passenger flight in October 15, 1932. Air India International Limited was established in early 1948 and its first flight took off on the Bombay (Mumbai)-London air route. The nationalization of airlines took place in 1953 (1).

Two-seat *ab-intio* lightplane: HANSA

The Hansa programme is National Aerospace Laboratories' (NAL) first foray in its initiative to create a vibrant Indian civil aviation industry. Launched around 1990, it involves the indigenous design, development, fabrication and flight-testing of an all-composite 2-seat aircraft. The first production version (VT-HNS) had its maiden flights on 14 May 1999. Hansa aircraft (**Figure 24**) could replace the aging trainers in India's 38 operational flying clubs. The maximum cruise speed is 175 kmph and the maximum range it can travel is 842 km (endurance: 4 hours).

Figure 24. Two-seater trainer light plane, Hansa

14 seater multi-role aircraft: SARAS

SARAS is the first civilian passenger aircraft being designed and developed in India by NAL with a capacity of 14 seats, extendable up to 18 seats. It is a multi-role aircraft with feeder airline and air taxi operations as its primary roles. It can also be used in other roles like executive transport, light package carrier, remote sensing, aerial research vehicle, coast guard, border patrol, air ambulance and other community services. It is a twin-engine turboprop aircraft with a pressurized cabin. The cruise speed is 550 kmph and the range it can travel with 8 and 14 passengers is 976 and 462 km respectively. **Figure 25** shows the roll out of the first prototype on 4^{th} February 2003. The first flight is expected soon.

Figure 25.
Fourteen seater aircraft

Light Combat Aircraft (TEJAS)

The LCA (Tejas), India's state-of-the-art multi-role supersonic aircraft would be among the best in the world in its class. The programme aimed at development of an advanced fighter for the Indian Air Force. LCA TD1 and TD2 formation flights during the naming ceremony of the aircraft as TEJAS by the Prime Minister of India on May 4, 2003 is shown in **Figure 26**.

Figure 26. LCA TD1 and TD2

Advanced Light Helicopter (Dhruv)

Designed and developed by Hindustan Aeronautics Limited (HAL), ALH (**Figure 27**) is a unique multi-role, state-of-the-art, cost effective new generation helicopter. It is designed to meet the requirements of both civil and military operations. It can be used for search and rescue, disaster relief, offshore operations, emergency medical services and communication duties. It can accommodate 12 to 14 passengers and the cruise speed is 220 kmph.

Intermediate Jet Trainer - HJT 36

Hindustan Jet Trainer- 36 (**Figure 28**) is a new intermediate jet trainer, designed and developed by HAL. It will replace the aging HJT-16 (Kiran) trainer aircraft being presently used by the services for stage-II training of the pilots. All metallic structures have been designed for ease of maintenance and cost effectiveness. The aircraft has a maximum dive speed of 750 kmph, and maximum Mach number of 0.75.

Figure 27.
ALH (Dhruv: 12-14 seater)

Figure 28. HJT 36

CONCLUSIONS

The Wright brothers and their invention sparked a revolution as far reaching as the industrial and digital revolutions. But that revolution did not come by luck or accident. It was vision, and the application of scientific methodology that enabled Orville and Wilbur to carry the human race skyward. As we move through the 21st century, with each fly-by-wire fighter, each 550-seat airliner costing many years of work and many millions of rupees, it seems inconceivable that it all began with a few lengths of muslin cloth and a rickety engine, and incredible bravery or naivette 100 years ago. Engineering breakthroughs are not just mechanical or scientific but they are liberating forces that can continually improve people's lives.

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